



**BIOLOGICAL CONTROL OF BACTERIAL WILT IN TOMATO USING
BACILLUS spp.: ANTAGONISTIC MECHANISMS AND SUSTAINABLE
PLANT PROTECTION**

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Abstract

The present study reviews the biological potential of *Bacillus* spp. for controlling bacterial wilt of tomato (*Solanum lycopersicum* L.), caused by members of the *Ralstonia solanacearum* species complex. Particular attention is given to the antagonistic properties of *Bacillus subtilis* and *Bacillus velezensis*, their ability to colonize plant roots, produce antimicrobial metabolites, and activate plant defense mechanisms. Published experimental findings were analyzed to compare the effectiveness of bacterial biological control agents. Previous investigations demonstrated that selected *B. subtilis* isolates exhibited biocontrol efficacy ranging from 13.3% to 80%, while a recent greenhouse study reported an 88.13% reduction in bacterial wilt incidence following combined application of selected *B. velezensis* isolates. These results indicate considerable potential for developing environmentally sustainable microbial preparations. However, the effectiveness of biological control depends on strain characteristics, cultivation conditions, and application methods. The review highlights the importance of selecting locally adapted bacterial isolates for future plant protection research in Uzbekistan.

Keywords

Bacillus subtilis, *Bacillus velezensis*, *Ralstonia solanacearum*, tomato, bacterial wilt, biological control, biopesticides, plant protection.



Introduction. Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated vegetable crops and plays an important role in agricultural production and food security. However, tomato cultivation is affected by numerous bacterial, fungal, and viral diseases, resulting in significant economic losses.

Bacterial wilt, associated with the *Ralstonia solanacearum* species complex, is considered a serious soil-borne disease. The pathogen penetrates plant roots, colonizes vascular tissues, and disrupts water transport. Typical symptoms include leaf wilting, vascular discoloration, reduced plant growth, and eventual plant death.

According to published research, severe bacterial wilt outbreaks may cause substantial losses in tomato production, reaching up to 100% under particularly unfavorable disease conditions [1].

Conventional disease management approaches include resistant cultivars, crop rotation, sanitation, and soil treatments. However, the persistence of pathogenic bacteria in soil and their broad host range complicate disease control.

In recent years, biological control using beneficial rhizobacteria has received increasing scientific attention. Species belonging to the genus *Bacillus* are particularly promising because many strains produce antimicrobial metabolites, form resistant endospores, colonize the rhizosphere, and stimulate plant defense responses [2, 3].

The objective of this review was to analyze published experimental evidence on the biological control of tomato bacterial wilt using *Bacillus* spp. and evaluate the prospects for developing effective microbial plant protection technologies.

Materials and Methods

The study was conducted as a literature-based comparative review of scientific publications addressing bacterial wilt of tomato and biological control using *Bacillus* species.



Published studies were selected according to their relevance to three principal research directions: antagonistic activity against *Ralstonia* pathogens, biological control efficacy under greenhouse or field conditions, and microbial mechanisms contributing to disease suppression.

Quantitative findings were extracted from selected experimental publications. Particular attention was given to biocontrol efficacy, relative disease incidence, and treatment effectiveness.

The results were compared descriptively because the reviewed investigations differed in experimental design, bacterial strains, disease assessment methods, and environmental conditions.

For interpretation, biological control efficacy can be expressed as:

$$BCE = \frac{DI_c - DI_t}{DI_c} \times 100$$

where:

- *BCE* — biological control efficacy (%);
- *DI_c* — disease incidence or severity in the untreated control;
- *DI_t* — corresponding disease incidence or severity in the treated group.

This formula is appropriate when the same disease indicator is used for both experimental groups.

Results and Discussion

Analysis of the selected literature demonstrated that the biological effectiveness of *Bacillus* strains varies considerably depending on microbial characteristics and experimental conditions.

Chen et al. [2] investigated 60 naturally occurring *Bacillus subtilis* isolates and identified six strains exhibiting greater than 50% biological control efficacy against



tomato bacterial wilt under greenhouse conditions. Across the tested wild isolates, efficacy ranged from 13.3% to 80%.

The researchers also established that bacterial biofilm formation played a significant role in the colonization of tomato roots and disease suppression.

In a separate investigation, Sun et al. [3] demonstrated that *B. subtilis* strain R31 significantly reduced bacterial wilt incidence. The antagonistic activity was associated with antimicrobial lipopeptides, rhizosphere colonization, and changes in microbial community composition.

More recent research on *B. velezensis* reported an 88.13% reduction in disease incidence following the combined application of selected bacterial isolates under greenhouse conditions [4].

These results indicate that beneficial bacteria can suppress bacterial wilt through several complementary mechanisms.

Table 1. Quantitative results of selected studies on biological control of tomato bacterial wilt

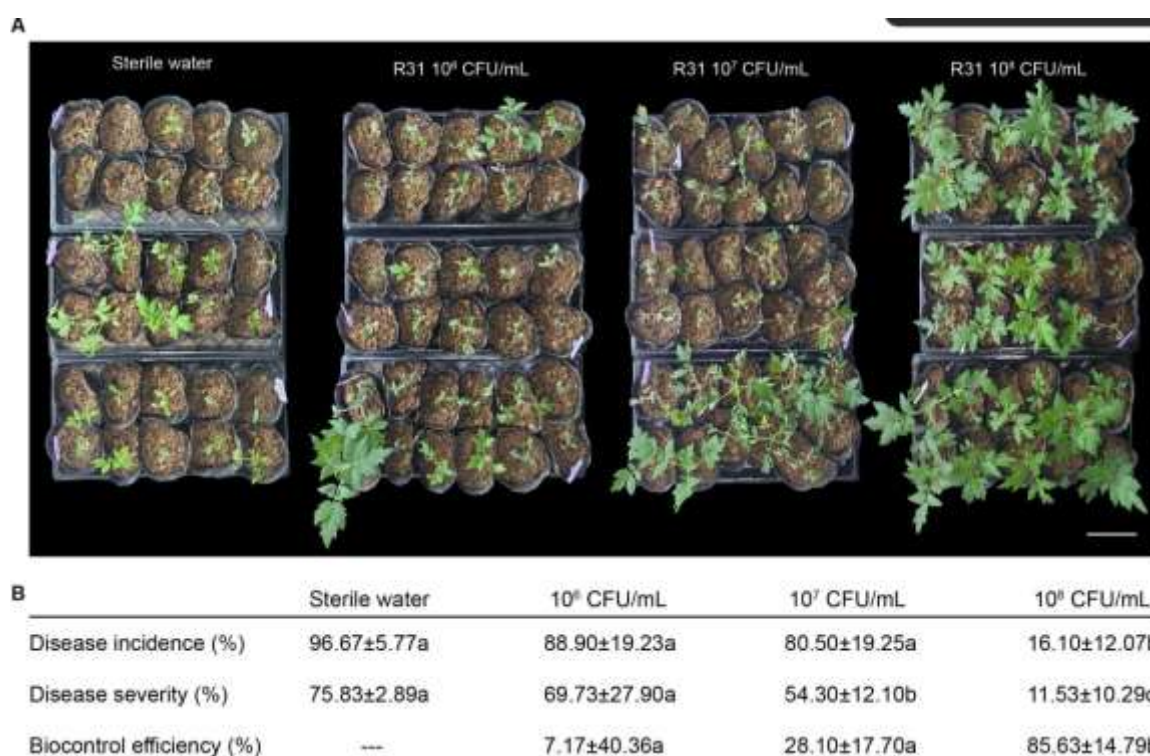
Study	Biological agent	Reported result
Chen et al. (2013)	<i>B. subtilis</i> wild isolates	13.3–80% biocontrol efficacy
Chen et al. (2013)	<i>B. subtilis</i> strain 3610	70.3% biocontrol efficacy
Chen et al. (2013)	<i>B. subtilis</i> strain PY79	28.9% biocontrol efficacy
Guo et al. (2004)	<i>Bacillus</i> sp. BB11	68.4% disease reduction in one field trial
Recent study (2026)	Combined <i>B. velezensis</i> isolates	88.13% reduction in disease incidence

The data in Table 1 originate from independent published experiments [2, 4, 5]. They should not be interpreted as results of a single controlled comparison.

Statistical analysis and graphical interpretation

The published findings reveal substantial variation in biological control effectiveness. In the Chen et al. study, the difference between the model strains 3610 and PY79 was 41.4 percentage points, emphasizing the importance of bacterial strain selection.

Sources: Chen et al. (2013), Guo et al. (2004), and the 2026 *B. velezensis* study. The percentages represent different experimental settings and should not be treated as a controlled head-to-head comparison.



Biological control research involving beneficial bacteria and tomato plants.

The diagram demonstrates that selected bacterial strains achieved markedly different levels of disease suppression. This variability supports the importance of selecting effective microorganisms for biological control applications.



In addition, bacterial biofilm formation, antimicrobial lipopeptide production, and rhizosphere colonization appear to be important mechanisms contributing to the suppression of *Ralstonia* pathogens.

For practical agricultural applications, further investigations should evaluate the stability, environmental adaptability, and field performance of locally isolated *Bacillus* strains.

Conclusion

The reviewed scientific evidence demonstrates that *Bacillus* spp. possess considerable potential as biological control agents against bacterial wilt of tomato.

Selected strains of *B. subtilis* and *B. velezensis* have demonstrated substantial disease suppression under experimental conditions. Published efficacy values ranged from 13.3% to 80% among tested wild *B. subtilis* isolates, while a recent investigation reported an 88.13% reduction in disease incidence following combined treatment with *B. velezensis* isolates.

The main mechanisms contributing to biological protection include antimicrobial metabolite production, root colonization, biofilm formation, and stimulation of plant defense systems.

Future research should prioritize the isolation of indigenous *Bacillus* strains from agricultural soils of Uzbekistan, evaluation of their antagonistic activity, and development of stable microbial formulations suitable for greenhouse and field applications.

References

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